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EASTERN BLUE-STEM OF THE BLACK RASPBERRY A 4: 14

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EASTERN BLUE-STEM OF THE BLACK RASPBERRY.

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In a locality just west of Cleveland, Ohio, the growing of black raspberries has been an industry of importance for many years. During the last decade or more, however, the acreage planted to this fruit has been reduced, not because of the lack of a good market, but because yields have decreased. Plantations do not live or produce adequate crops for as long a period of years as they formerly did, and therefore although high prices have been received for the fruit the net profits have dwindled until the business, for many growers, has ceased to be attractive. This development is typical of the history of a number of regions where black raspberries were at one time a major crop.

Anthracnose, cane-blight, and crown-gall, as well as other diseases of the raspberry, occur throughout the region, but apparently not with such severity as to account for the decline of the industry. The low yields and short life of many plantations have been found to be closely associated with an unhealthy condition of the plants, not corresponding with the symptoms of any previously described disease, but recognized by certain growers and called curly leaf or blue-stem. This condition can be detected in various stages by definite symptoms.

NAME.

The term "curly leaf," or "leaf-curl," aptly describes a prominent symptom, but does not serve to distinguish this disease from the yellows, or leaf-curl, which is most common on red raspberries but also occurs on blackcaps in Ohio. The other local name, blue-stem, has the disadvantage of having been applied to a disease of the black raspberry which occurs in the State of Washington. The disease noted in Ohio and other Eastern States appears to be quite different from that reported in Washington. The name blue-stem is descrip-

tive of the trouble as it occurs in the Dover-Avon locality and was adopted, subject to change, early in the course of the investigations there. It has become established locally, and it is used in the present circular in the modified form, "eastern blue-stem," to avoid confusion with the disease occurring on the Pacific coast.

DISTRIBUTION AND DAMAGE.

Eastern blue-stem is not confined to one locality, but is apparently a trouble of major importance in a number of regions where black raspberries are grown intensively, and probably it is still more widely scattered in small gardens. It has been found generally distributed throughout the raspberry-growing area near Cleveland: to the west in the Dover-Avon district of Cuyahoga and Lorain Counties and to the east in the nursery section of Lake County. During 1921 it was reported by Ohio nursery inspectors from the additional counties of Ashtabula, Belmont, and Stark. This disease has been discovered in New York in greater or less abundance in the counties of Chautauqua, Erie, Monroe, Ontario, and Yates. In Berrien County, Mich., scattered plants affected with the disease were found in fields and nurseries. In Wisconsin a few diseased plants were found in Dane and Jefferson Counties.

This incomplete survey indicates that the eastern blue-stem is present not only in northern Ohio but also in other sections to the east, but that in the districts visited west of Ohio (southwestern Michigan and southern Wisconsin) it has not become so firmly established. It is important that more thorough and accurate surveys be made in order that its extent and seriousness may be known.

It is impossible to estimate closely the extent of the damage. In the Dover-Avon district, where the most thorough investigation has been made, individual fields showed infections ranging from zero to over 75 per cent of the plants. The direct loss in the reduction of the crop from fields in this district alone can be estimated conservatively at not less than \$10,000 a year; the loss suffered through shortening the productive life of plantations, necessitating renewal and curtailing net profits, is probably much greater. The losses appear not to fluctuate widely from season to season, as in the case of many other diseases, but to increase slightly each year. They are sufficient to explain the gradual reduction in the acreage planted to raspberries or the slow movement of the center of commercial production from one locality to another. The total loss from blue-stem in the northeastern part of the United States is probably large.

SYMPTOMS OF THE DISEASE.

The general effect of eastern blue-stem upon a raspberry plant is a gradual stunting and reduction of vigor. When affected tips are

planted they make little growth and by fall are easily recognized as sickly. The following spring they may start feebly or not at all.

On plants which have become infected in the field the stunting may not be apparent or pronounced the first season, and the plants may ripen a good crop of fruit, but the berries will usually be slightly smaller and more inclined to crumble. The shoots may be normal in number but shorter and less vigorous. Food storage is apparently hindered, so that the second season the plant will be smaller, the fruit inferior in size, quality, and quantity, the harvest season shortened, and the shoots produced few and weak. The third spring part or all of the canes may fail to grow, apparently having been winterkilled, or they may make a feeble start. The growth of shoots is very weak, and the plants frequently die during the summer or the succeeding winter. The rapidity with which the disease works varies, but from two to three years seems to be the average length of life of a plant after it first shows symptoms of the malady.

In no case has the recovery of a plant been observed after its stems or leaves denoted the presence of eastern blue-stem.

An examination of diseased plants shows a peculiar curling of the upper leaves. The margins and veins do not arch downward, but the midribs of the leaflets are hooked or recurved. The first visible symptom of the disease may be a peculiar sharp bend of the midrib near its tip. The curling is most pronounced on the younger leaves of the most rapidly growing parts, especially, therefore, on the shoots, where it begins to show when they have reached a height of a few inches. (Pl. I.) This curling is difficult to distinguish immediately after the shoots are topped back in midsummer, but appears again conspicuously on leaves of the lateral branches, which soon develop. The same symptoms can usually be seen, though less plainly on the leaves of fruiting canes. The leaves on diseased shoots are sometimes slightly crowded as compared with those on healthy plants and in early stages of the disease. With their gracefully curved shape they frequently give an appearance of pleasing luxuriance of foliage. This has at times led uninformed growers to think that young but badly diseased fields were making unusually good wood for the next season's crop, only to be disappointed in the spring at the large number of canes which failed to survive the winter.

A uniform mottling of the leaves usually accompanies their change of shape. The diseased leaves show small areas of yellowish green scattered over the surface. These do not later take on the bronze color so often associated with the common leaf-curl. In later stages of the disease and late in the season, this mottling often becomes

very pronounced; at other times it may be so faint as to be of little aid in diagnosis.

In the Dover-Avon district a conspicuous and constant symptom is the discoloration of the stems of shoots which give rise to the name blue-stem. The color is a very dark shade of blue or violet blue, approximating indulin blue as illustrated by Ridgway in his color guide. It appears as dots, very small spots, or longitudinal stripes not unlike broad pencil marks irregularly placed and often confluent. This discoloration occurs commonly at or near the surface of the ground, upward on the stem as high as 2 feet or more, and frequently near the bases of lateral branches. A broad continuous stripe along one side of the shoot is rarely found, but in extreme cases the marks may be so numerous as to turn the entire lower part of the stem to deep blue. The discoloration lies in the green chlorophyll layer of the stem, not extending into the wood or pith. It may appear when the shoots are a few inches high and persists until the ripening of the wood in the fall. On fruiting canes of diseased plants the petioles and stems of lateral branches often show short, very narrow, longitudinal streaks of brown or purplish brown. The extent to which the color develops seems to vary with the variety of raspberry, age of the plant, and the locality where it is grown; in many places, unfortunately, it is absent or occurs so irregularly as to be of no value in detecting the disease. Roots of diseased plants show no local abnormalities or necrosis.

Eastern blue-stem appears to be strictly systematic in character. Except in its earliest stages, the presence of the disease in one cane or shoot is usually accompanied by symptoms of the trouble in all other shoots from the same crown. In apparent exceptions there are frequently two crowns, one healthy and the other diseased, in the same hill. In some cases where slightly curled leaves have been found on the tip of only one shoot, this shoot has been removed at once; nevertheless, during the next season the whole plant developed symptoms of the disease. It has been the practice of certain growers to cut off at the ground all diseased plants when pruning the bushes just after harvest, but before winter these crowns throw up a number of tender shoots in which the curling and mottling of leaves, typical of blue-stem, are highly developed.

Plants in the early stages of the disease often reproduce by the rooting of the tips. Observations indicate that such progeny is always affected with blue-stem. This leads to the dissemination of the disease by means of nursery stock.

DISTINCTIONS BETWEEN EASTERN BLUE-STEM AND OTHER DISEASES.

The blue-stem of the black raspberry which occurs in the State of Washington is described as due to a fungous parasite which causes

a drying up of partially matured fruit, accompanied by wilting of the leaves and darkening of the canes. On young shoots the action is more rapid, the leaves wilting and turning brown and a blue-black color spreading, often over the entire cane, in the course of a few days. The symptoms of this disease are so different from those of the eastern blue-stem that there is no danger of confusing the two.

"Yellows," at least as it occurs on the cultivated red raspberry, has been found by Rankin, Hockey, and McCurry to include two diseases, which they call mosaic and leaf-curl. The latter, or a disease with practically identical symptoms, also occurs on certain varieties of black raspberries in Ohio, occasionally causing severe damage and presenting an appearance quite different from that of blue-stem, the symptoms of which have been described. In leaf-curl "the leaflets are very dark green, and the midrib and main lateral veins arch downward, causing a curling of the entire margin of the leaf. The tissue arches between the veins and causes a puckering along the veins." The stems, petioles, and leaves tend to be shorter or smaller and less flexible than usual, giving the plant an appearance of stiffness. Black raspberries affected with leaf-curl rarely root at the tip.

Another point of difference lies in the respective host ranges of the two diseases. What is apparently the leaf-curl has been found by the writer on several varieties of red raspberries, on purple canes, once on the Japanese wineberry (*Rubus phoenicolasius*), and also on two varieties of blackcaps, the Cumberland and Hoosier. Observations indicate that the Kansas and Plum Farmer varieties are very resistant to leaf-curl. It has not been seen on blackberries. As will be discussed in the next paragraph, no variety of blackcap has exhibited high resistance to blue-stem. The disease has not been recognized on red raspberries nor on the Japanese wineberry, but very similar abnormalities have been noted on certain blackberries.

KINDS AND VARIETIES OF PLANTS AFFECTED WITH EASTERN BLUE-STEM.

Only four varieties of black raspberries are grown on a commercial scale in the Dover-Avon district—Hoosier, Cumberland, Plum Farmer, and Kansas. All of these are subject to attacks of blue-stem, though not to the same degree. The Hoosier seems to be the most susceptible, the disease spreading and developing with great rapidity on this variety. The Kansas seems to possess the greatest resistance, although exceptional fields have been found in which the infection was as high as 20 per cent. The Cumberland and Plum Farmer, and also the Munger, are seriously susceptible. Eastern blue-stem has been noted on other varieties of blackcaps, par-

ticularly the Ohio and Gregg, in other sections of the country, but not under conditions such as to test the resistance of these sorts or to indicate that any variety is immune or very resistant. The disease has not been recognized on red raspberries, the Japanese wineberry, or on Eldorado or Erie blackberries.

Growing near badly diseased raspberry plantations, plants of a small wild species of blackberry have been found whose leaves showed in a high degree the curling and mottling characteristic of blue-stem. In one patch of Taylor blackberries near a badly infested field of blackcaps, nearly all bushes showed the very pronounced curling of the leaves typical of blue-stem. There were dark brownish streaks along the stems, and the crop of fruit was said to have been very small and worthless. In these cases the symptoms were such as to suggest the strong probability that the blackberries were suffering from blue-stem.

It is important to ascertain definitely the hosts which are capable of harboring blue-stem infection, as this knowledge has an important bearing on the problem of control.

CAUSE OF THE DISEASE.

Numerous factors suggested as causes of this diseased condition have been investigated. The trouble is apparently not due to the "running out" of varieties as the result of long-continued vegetative propagation. It is possible that the disease spreads or develops more rapidly or severely on certain sites and soils than elsewhere, but a large amount of evidence indicates that it is not induced primarily by environmental factors.

Microscopic examination of tissues of leaves, petioles, stems, and roots of plants affected with blue-stem has not indicated the constant presence anywhere of bacteria or fungi. Isolations from all parts of diseased plants have not yielded any organism which has proved capable of reproducing the disease.

Several features point strongly toward the probability that the trouble is a disease of the mosaic type. The characteristic deformity and mottling of the leaves and the stunting and final death of the plants as well as the transmission of the malady to vegetative progeny all accord with this supposition. At any rate, conditions parallel to all of these are found in a number of mosaic diseases.

MEANS OF DISSEMINATION.

The eastern blue-stem often becomes established in a new field through the planting of diseased tips. Several consecutive plants in a row are sometimes found showing blue-stem symptoms. In younger fields at least, this appears to be due less frequently to the



HEALTHY AND DISEASED BLACK RASPBERRY TIPS.

FIG. 1.—Healthy tips. FIG. 2.—Tips affected with eastern blue-stem, showing the shortening of the nodes and the recurving of the tip and midrib which are characteristic of this disease.

disease having been carried from one plant to the next in the field than to the manner of planting. The man who set or dropped the plants picked up a handful of tips, several of which came from one diseased mother plant, and dropped or planted these one after the other in the row.

At the time of digging tips it is impossible to recognize bushes in the early stages of blue-stem, and the dormant tips from diseased plants show no sign of the disease. Neither do the symptoms of blue-stem appear sufficiently early in the spring to permit their detection, even if the plants are not dug and reset until they have made a growth of several inches. The most careful inspection of tips in the field, therefore, will not insure freedom from the trouble.

After diseased tips have been set, blue-stem spreads to other plants in the field, though in most cases rather slowly. The means of its dissemination are not known. Unfortunately, all attempts to transmit the malady artificially have failed. The juice of diseased plants expressed and injected into various parts of healthy plants has been ineffective. The tissue of affected plants has been macerated and bits placed in wounds made in healthy plants without inducing the disease. Other experiments have given negative results. It has been impossible to test under controlled conditions the important possibility of transmission by means of insects, such as plant lice. In the case of a number of mosaic diseases plant lice are the most efficient agents of transmission and are habitually used for the inoculation of healthy plants.

Observations indicate that blue-stem has spread from one field to another over considerable distances, at least 200 or 300 yards, although infection is much more frequent where fields are not so widely separated. It has not been possible to estimate closely the limit of its spread, especially since the means of transmission is not known. In numerous cases it has been found impossible to keep the disease out of young fields set in the immediate vicinity of badly infected patches. Some of these instances have been checked by the planting of tips from the same mother fields in locations where they were not exposed to infection. In the latter cases it was found possible to keep the young fields free from blue-stem. Similarly, in the case of old fields practical control of blue-stem has not been secured when the disease has been left in adjoining or neighboring plantations.

Evidence supports the view that eastern blue-stem spreads most rapidly in those fields which are making the most vigorous growth; that new infections take place most frequently when the plants or some of their parts are in a tender, succulent condition because of rapid growth; and that the spread of the disease seems to halt

when this rapid growth stops. Infection does occur, sometimes even to an alarming extent, in fields of ordinary or even subaverage condition of vigor, but in old, neglected patches in infected territory it is frequently difficult to find the disease, the old canes having died and few new ones having developed. It is possible that this apparent relation between vigorous growth and the spread of the disease has some connection with the degree of susceptibility of different varieties. Under conditions at Avon Lake the Hoosier, which is the most susceptible variety, makes the most rapid, tender growth, while the Kansas, which shows some degree of resistance, makes the slowest and least abundant growth.

CONTROL.

No variety which has been tested possesses sufficient resistance to blue-stem to justify its exclusive adoption in infected districts, nor can any single variety answer all demands as to quality, season of ripening, market, and soil adaptation. Selection experiments have been started in the hope of finding resistant strains of several commercial varieties. In the case of the Plum Farmer the results already give some encouragement.

Observations regarding blue-stem would not lead one to expect its control by fungicidal sprays. Applications of lime-sulphur for the control of anthracnose on plats where blue-stem was prevalent have had no apparent effect.

Since the disease may be carried into new plantations by the setting of tips from affected plants, it is obviously important to get stock from fields where blue-stem does not occur. The value of healthy tips has been well established, but early in the present investigation they proved hard to secure. Failing to locate a thoroughly reliable source of stock an attempt was made in 1921 to develop such a source by eradication of the disease from a controlled territory. An area 2 miles long and nearly as wide was selected about the village of Avon Lake, Ohio, at the very edge of the raspberry-growing district. Blue-stem infection in this area was low (1.6 per cent of all plants), but the disease was widely scattered throughout the 150 acres of black raspberries. Two or more inspections were made of all fields. Plants found affected with blue-stem (also those showing signs of leaf-curl) were marked, and in nearly all cases these diseased plants were removed by the owners. A number of old fields were destroyed after harvest. In a few other isolated fields (aggregating about 8 acres) which were to be destroyed after the harvest of 1922, the diseased plants were allowed to remain, but the disease was carefully rogued out of about 130 acres of raspberries; and, if previous experiments and extended observations are to be considered an indication,

most of the fields in this area will furnish plants in the spring of 1922 with a very high probability of freedom from blue-stem. With cooperation of the growers assured it is hoped that the eradication of blue-stem from this territory will be completed in 1922.

As to control of the disease in fields where it has already become established, most of the roguing experiments to date have been successful in cases where treated fields were at a distance from all other infected plantations, but not where they were liable to severe reinfection. Under present methods, therefore, the control of blue-stem in any intensive raspberry-growing district requires simultaneous action by owners of adjacent or neighboring fields and preferably the cooperation of all raspberry growers in an area of considerable extent.

The eradication of blue-stem from fields of "creepers" (plants in their first season of growth) has been accomplished by roguing in August and September and again the following June. Inspection of "lowbushes" (plants in their second season) is more difficult and can probably be better done before harvest. Apparently the roguing of mature fields can be done just as effectively and more quickly and thoroughly following the removal of old canes after harvest, as blue-stem symptoms are most conspicuous on the young growth. The results of roguing mature or old fields in the Dover-Avon district have been very encouraging, and where the amount of infection was small they have frequently been successful; but they have not progressed so far as to prove that bearing plantations where the proportion of blue-stem is high can be freed from the disease by means of inspection and roguing. Success in such an attempt depends upon recognition of the disease in its very early stages. This is apparently possible with trained observers in the Dover-Avon locality, where the discoloration of the stems of shoots is an early symptom of the disease. The evidence is insufficient to show whether this is equally true in regions where diagnosis must be based largely on the curling of the leaves. In any case, however, careful roguing of old fields will apparently reduce the sources of infection to such a degree that the disease can be kept out of near-by young plantations. After a grower learns to recognize the disease he can detect and remove affected plants with little loss of time whenever he is working in the field.

Since there has been no indication that an infective agent persists in the soil, it is apparently safe to plant a healthy tip in the place from which a bush suffering from blue-stem has been removed.

The following recommendations for the control of eastern blue-stem of the black raspberry are based on present knowledge of the disease:

Nursery stock free from the disease should be secured and set as far as practicable from diseased plantations. The young fields should be carefully watched, and any plants which develop symptoms of blue-stem should be promptly removed and destroyed. Sources of infection should be eliminated as far as possible by the destruction or thorough and repeated roguing of older fields. Where diseased plants have been removed, they may be replaced by healthy tips.

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